A New Approach to Monitoring Solvent Extraction Processes for the Nuclear Industry

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A New Approach to Monitoring Solvent Extraction Processes for the Nuclear Industry
Supported to Inform in Design of INL’s Beartooth Testbed

- Infrastructure includes glove box lines, dissolution equipment, and solvent extraction equipment.
- Solvent extraction flowsheets
  - Extraction, scrub, strip, solvent reconditioning
- A highly configurable testbed that will accommodate numerous flowsheets by changing line inlets and outlets.
  - PUREX, UREX, THOREX, etc.
- Test novel separation methods.
- Train early-career separation scientists.
- Incorporate novel monitoring techniques.
Non-traditional Sensors

- RGB Color
- Temperature
- Conductivity
- pH
- Aqueous Feed Tank
- Organic Feed Tank
- Pump
- Heater
- Tank Level Sensor
- Aqueous Flow
- Organic Flow
- Motor Current
- Density/Viscosity
- Temperature
- Conductivity
- pH
- Multimodal sensor
- Vibration/Acoustic/Seismic
- Thermal Camera
Novel Monitoring

- Can data be used to improve extraction process?
- Can data be used to predict equipment failure?
- Can data validate current sensor measurements?
- Can data be used in development of a digital twin?
Thermal Camera Measurements for Leak Detection

- Develop model to alert process operators of a leak event.
- Data augmentation was used to generate new images and improve model robustness:
  - Shear, Zoom, Flip, and image modification techniques
Performed Purposeful Leaks

- Three different angles.
- Three different leak sizes.
- Three different leak locations.
  - contactor system
  - common sink
Relationship of Color to Concentration

- Ran a series of experiments:
  - Solutions of known concentrations.
    - Blue, pink, yellow
  - Measurements taken with Red-Green-Blue color sensor.
Vibration Measurements to Determine O to A

- Set the aqueous pump to a constant flow rate or 16.5%
- Set the organic pump to 28%, then increased in 1% increments, finally increased in 5% increments
- The ratio of frequencies approximately matched the ratio of flow rates.
  - Initially:
    - $\frac{28\%}{16.5\%}=1.7$
    - $\frac{7.5}{4.6}=1.6$
  - At maximum:
    - $\frac{90\%}{16.5\%}=5.5$
    - $\frac{26}{4.6}=5.7$
Power spectra slide

• Skeleton slide

[Image of power spectra graphs for Organic Pump and Aqueous Pump with frequency and time scales]
Acoustic Measurements Showing Rate of Contactor Motors

- Contactor motors were turned on one by one initially and then operated for approximately two hours.
- At around 15:19 the rate of operation of contactor 2 was changed from 3000 to 2940 RPM.
- Spectrogram on left - sensor in room ~14 m from contactor 1
- Spectrogram on right – sensor outdoors ~40 m from contactor 1, signal propagated through 4 walls.
Another RPM slide

- Skeleton slide
Data Integration into Deep Lynx

- Began storing a portion of data into INL's data warehouse.
- Nodes are sensors.
- Edges are relationships.
- 8 of 11 datasets have been ingested.
Conclusions

• Use of thermal camera
• Vibration sensors
• Color sensor
• Acoustic sensors
Battelle Energy Alliance manages INL for the U.S. Department of Energy’s Office of Nuclear Energy. INL is the nation’s center for nuclear energy research and development, and also performs research in each of DOE’s strategic goal areas: energy, national security, science and the environment.